

conductivity has been found to be the same as that of their electrical conductivity.

As regards the *magnetic permeability* of these alloys, the order is very different from that of their electric conductivity. The most highly permeable alloys are those formed of aluminium and silicon with iron. In fact, the magnetic permeability of an alloy of iron with $2\frac{1}{2}$ per cent. of silicon exceeds that of the best and purest annealed iron up to a field of 10 C.G.S. units. Still more remarkable is a pure and well annealed alloy of aluminium and iron; although it contains a considerable percentage of non-magnetic elements, its magnetic permeability and maximum induction up to a field of 60 units exceeds the best and purest annealed iron that I can obtain, a specimen of Swedish charcoal iron containing 99.9 per cent. of iron, all the specimens having been subjected to a precisely similar annealing process.

It is possible the increased magnetic susceptibility given to iron by aluminium, and to a less extent by silicon, may be due to the strong chemical affinity which these elements have for oxygen, whereby any of this gas which might be dissociated in the molten iron would be removed, and the texture of the metal thus rendered closer and more uniform. In the same way, by combining with the oxygen, they would remove, as my colleague Professor Hartley suggests, traces of oxide of iron, more or less diffused through all iron; and the presence of which would certainly lower the magnetic susceptibility.

The remarkable magnetic properties of these two alloys, especially of the aluminium-iron alloy, is a matter not only of considerable theoretic interest but obviously is also of great practical importance in electrical engineering.

“On a Pair of Ciliated Grooves in the Brain of the Ammocæte apparently serving to promote the Circulation of the Fluid in the Brain-cavity.” By ARTHUR DENDY, D.Sc., F.L.S., Professor of Biology in the Canterbury College, University of New Zealand. Communicated by Professor G. B. HOWES, LL.D., F.R.S. Received February 7,—Read February 20, 1902.

The peculiar and apparently hitherto undescribed structures which form the subject of the present communication, were first discovered in the course of an as yet unfinished investigation of the parietal organs in the New Zealand Lamprey (*Geotria australis*). The Ammocæte of this interesting species is known to us only through two specimens:

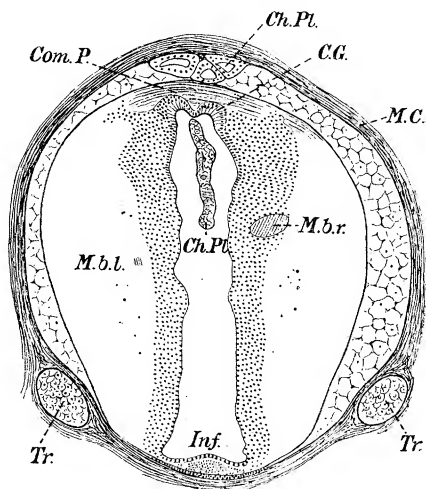
one of these was briefly described by Kner in 1869*; the other was for many years in the Museum of the Otago University, Dunedin, and was forwarded to me for investigation by the present curator, Professor W. B. Benham, D.Sc., to whom I desire to express my indebtedness for his great kindness.

The specimen which I have thus had the opportunity of investigating was labelled in the handwriting of the late Professor T. J. Parker, F.R.S.—“*Ammocœtes* stage of *Geotria*—Opoho Creek. Jany., '84. Chromic and Osmic.” It had evidently been preserved with the utmost care, and proved, in spite of its age, to be in an admirable state for histological investigation.

The total length of the specimen was about 57 mm., and the greatest diameter in the middle 3·5 mm. With a view especially to the study of the parietal organs, the head region was cut into a series of transverse sections by the usual paraffin method, and the sections were stained on the slide; for staining, carbol-fuchsin proved satisfactory.

On examination, the sections thus prepared showed not only a well-developed parietal eye and the structures usually associated therewith, but also a pair of conspicuous ciliated grooves lying in the roof of the brain in the neighbourhood of the posterior commissure. These grooves run longitudinally from the recessus sub-pinealis to the hinder margin of the posterior commissure. They are most conspicuous beneath the commissure itself (figs. 1, 2), in which region they are

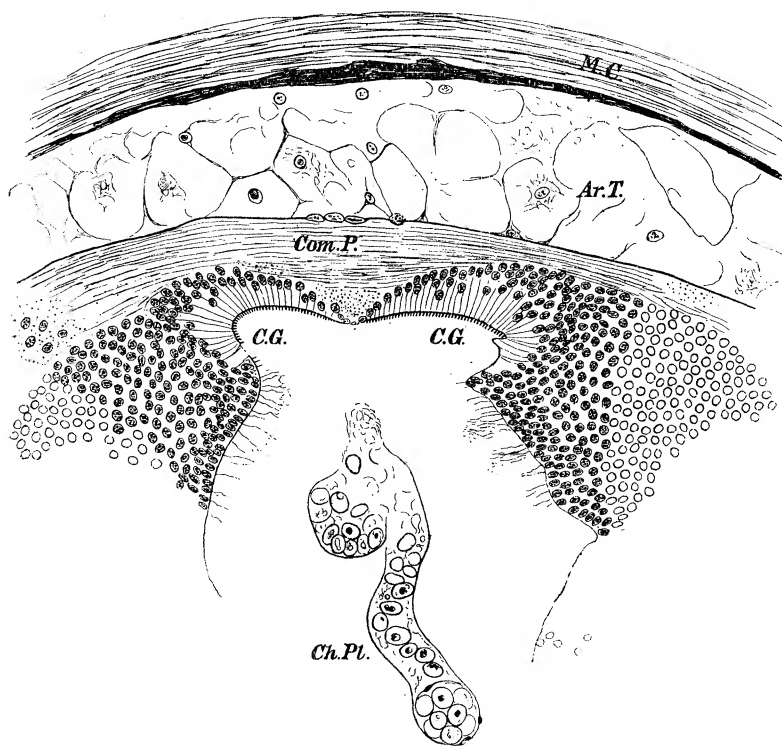
FIG. 1.



* “Reise der Österreichischen Fregatte *Novara* um die Erde,” ‘Zoologie,’ Bd. I, Fische, p. 421.

lined by a sharply defined epithelium of very long columnar cells, totally different in appearance from the epithelium which lines the remainder of the brain-cavity. The inner margins of the two grooves in this region touch one another in the middle line. Their lumina are deeply concave and open widely into the brain-cavity, which is here represented by a rather narrow vertical slit, terminating below

FIG. 2.

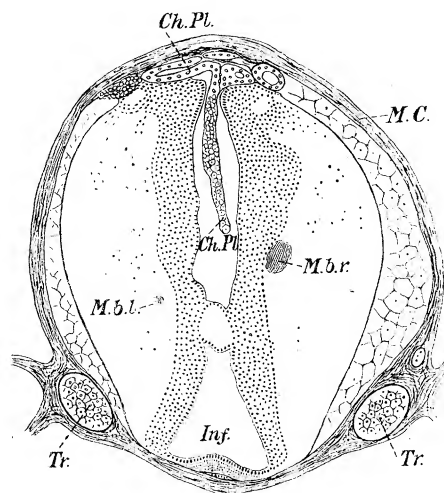


in the infundibulum (fig. 1, Inf.). Thus the cross-section of the two ciliated grooves lying beneath the posterior commissure has the form of the figure ∞ . Their lining epithelium, as already pointed out, is conspicuously different from the lining epithelium of the brain-cavity elsewhere. It is composed of narrow columnar cells with conspicuous nuclei (fig. 2). While very short at the margins of the grooves, these cells gradually increase in length towards the middle, so that the lining epithelium is very much thicker in the middle of each groove than it is at the two edges. The inner surface of each groove is covered by a thick coating of very short cilia. The transition from

the epithelium which lines the grooves to that which lines the adjacent parts of the brain-cavity takes place abruptly, and there are indications on the latter of very much longer cilia than occur in the grooves. As far back as 1873, indeed, Langerhans pointed out in his researches on *Petromyzon planeri* that the ventricles of the brain are lined with ciliated cylinder-epithelium.*

The upper and inner part of each groove is in this region imbedded in the substance of the posterior commissure; the lower and outer portion in the mass of cells which forms the inner part of the brain substance (fig. 2). Anteriorly the two grooves diverge from one another on the roof of the recessus sub-pinealis, and disappear in the deep crevices between the ganglia habenulæ and the side walls of the brain. Posteriorly they terminate at the hinder margin of the posterior commissure. Immediately behind this point the choroid plexus of the mid-brain dips down into the aquæductus Sylvii, or iter, in the shape of a thin vertical lamella, which forms a highly vascular longitudinal septum dividing the upper part of the iter into right and left halves (fig. 3). The anterior portion of this septum is visible

FIG. 3.



in sections beneath the ciliated grooves in the region of the posterior commissure (fig. 1), while it extends backwards throughout the whole or very nearly the whole length of the mid-brain.

Thanks to the kindness of Dr. S. J. Hickson, F.R.S., Professor of

* 'Berichte über die Verhandlungen der Naturforschenden Gesellschaft zu Freiburg i. B.,' vol. 6, Heft 3, p. 83.

Zoology in the Owens College, I have been able in a striking manner to confirm the results thus obtained in the New Zealand *Ammocæte* by an investigation of the corresponding organs in one of the European species. Professor Hickson kindly placed at my disposal for the purposes of this investigation a series of transverse sections, which had been cut a short while before by his assistant, but which he had not yet examined, and I was delighted to find in these, without the slightest difficulty, the structures which I had previously discovered in New Zealand.

The Owens College *Ammocæte* was, to judge from the size of the sections, considerably older than the New Zealand specimen, and this possibly accounts for certain differences in the arrangement of the parts under discussion. It appears also to have been treated with osmic acid, while the staining was effected by means of iron Brazilin. The columnar epithelium of the ciliated grooves is perhaps not quite in such a good state of preservation histologically as in the New Zealand specimen, but evidently has much the same character. Beneath the posterior commissure the grooves are widely separated from one another (fig. 4) instead of being in close contact. Anteriorly (fig. 5) they are I think better defined than in the New Zealand specimen, and the left one can be traced a good deal further forwards

FIG. 4.

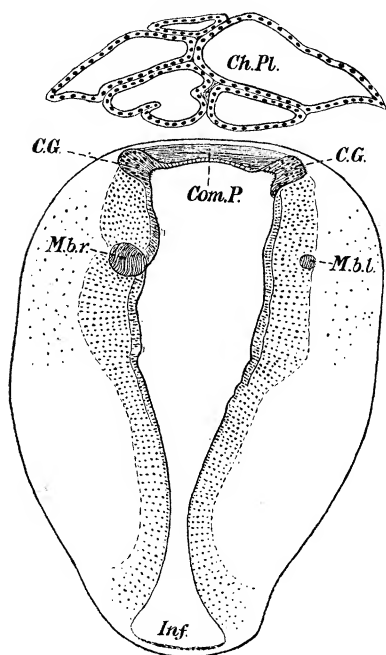
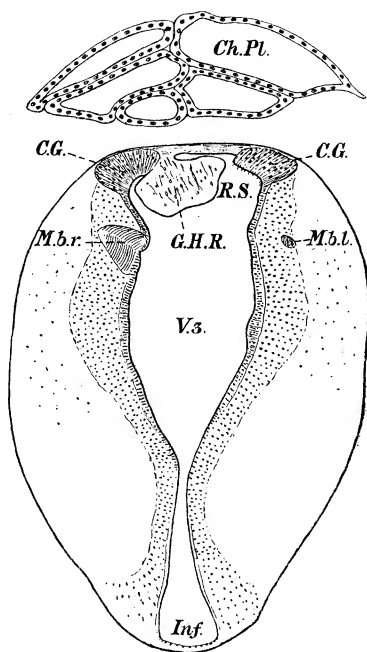
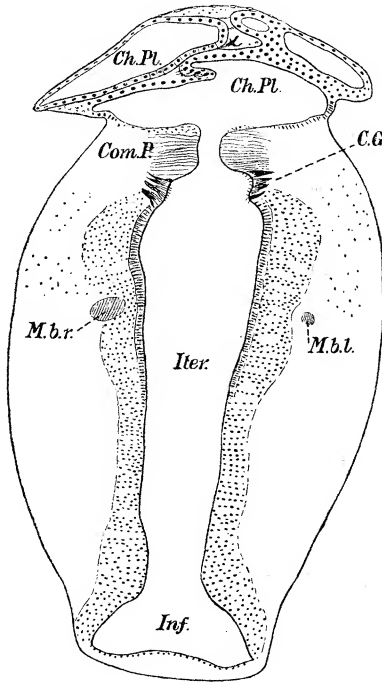


FIG. 5.



than the right, owing apparently to the great development of the right ganglion habenulæ, which projects into the brain-cavity and more or less blocks up the angle between roof and side wall. Posteriorly (fig. 6) they appear to terminate—as grooves—at about

FIG. 6.



the level of the hinder margin of the posterior commissure, but a band of long columnar cells appears to be continued backwards for a short distance after their groove-like character has disappeared, so that we find such a band on either side, bordering the narrow opening between the iter below and the cavity of the choroid plexus of the mid-brain above.

The most striking difference as compared with the New Zealand *Ammocete* concerns the arrangement of the choroid plexus of the mid-brain, which no longer dips down into the iter in the form of a deep, continuous, vertical septum (compare figs. 3 and 6). (Such a septum is, however, simulated in the sections by a mass of granular material containing what look like nuclei irregularly scattered through it. This appearance, which is not represented in the figures, suggests that the septum has undergone degeneration, or possibly the granular mass is simply a coagulum containing the remains of cells shed from

the lining epithelium; it is, however, easily distinguished from the choroid plexus, to which it is attached above, and which has the usual relations. It seems most likely that the vertical septum, if it ever existed in the European form, has simply been withdrawn upwards in the course of development, to take part in the formation of the extensive tela choroidea which forms the roof of the mid-brain.)

The subject can hardly be dismissed without some attempt to explain the presence of the ciliated grooves, and it is by no means difficult to assign to them a probable function. Gaskell, as is well known, has endeavoured to prove that the tubular nature of the central nervous system of vertebrates may be accounted for by its derivation from the alimentary canal of an invertebrate ancestor. He asks,* "On any of the other theories, why is there a nerve tube found with a dilated anterior extremity? Why are the cerebral vesicles formed? Why the choroid plexuses? Why does that tube terminate in the anus? Why is there an infundibular prolongation?" Without attempting to answer all these questions, I venture to hope that the facts recorded in this communication may throw some light upon the function of the cavities of the central nervous system. It has already been suggested that these may aid in the process of gaseous interchange. Thus, H. Blanc "believes that the paraphysis is not a degenerating organ, but is of great importance in connection with the development of the choroid plexus. Like the last-named, it has probably to do with the gaseous interchanges which are carried on in the cavities of the ventricles."† Now gaseous interchange, or respiration in the widest sense of the term, must obviously be a very necessary function for the nerve-cells. These cells in the *Ammocete* lie, as is well-known, in the inner portion of the brain substance, which forms a thick layer, separated from the fluid in the brain-cavity by the lining epithelium. Their relative positions are such that gaseous interchange may take place freely between the fluid in the brain-cavity on the one hand, and the grey matter of the brain on the other; but in order that this interchange may continue effectually two other conditions must be fulfilled: (1) Means must be provided for removing from the fluid in the brain-cavity the waste matters which it takes up from the brain-substance, and in return providing it with fresh supplies of oxygen and perhaps also of dissolved nutriment; and (2) Means must also be provided for maintaining a circulation of the fluid in the brain-cavity itself. The first of these conditions is apparently fulfilled by the vascular choroid plexus, while the second is, I believe, fulfilled in the *Ammocete* to a large extent by the ciliated grooves described above, probably

* 'Journal of Anatomy and Physiology,' vol. 32, p. 545.

† H. Blanc, "Epiphysis and Paraphysis in *Salamandra atra*," 'Arch. Sci. Phys. Nat.,' vol. 10 (1900), pp. 571-2. Abstracted in 'Journal of Royal Microscopical Society,' June, 1901, p. 257.

acting in conjunction with the longer cilia which line other parts of the brain-cavity. The occurrence of cilia in some part or other of the central nervous system of vertebrates has been so often demonstrated* that it is hardly necessary to discuss other cases here, except to point out that their function is probably in all cases to promote the circulation of the brain-fluid.

As to the choroid plexuses of the vertebrate brain there can, I venture to think, be little doubt as to their importance in promoting the oxygenation of the brain-fluid. Especially suggestive from this point of view is the manner in which these plexuses sometimes project into the cavities of the ventricles. A good example of this is afforded by the vertical septum of the choroid plexus of the mid-brain in the New Zealand Ammocœte, as described above. This septum is highly vascular, and it is extremely significant that the ciliated grooves are so arranged as probably to direct a stream of brain-fluid along each side of it. Whether the direction of this stream is forwards or backwards, it is of course impossible to say without direct experiment. Personally, I am inclined to think that it will be found to flow forwards, and that the ciliated grooves may be looked upon as special organs for conveying an abundant supply of oxygenated fluid to the forepart of the brain (especially, perhaps, to the right ganglion habenulæ, which, as is well known, is enormously developed in the Lamprey, and apparently fulfils some important function in connection with the parietal organs). In the young Ammocœte the first choroid plexus, which may be supposed to be especially concerned in the respiration of the fore-brain, is not yet developed; the second and third choroid plexuses, belonging respectively to the mid- and hind-brain, are, on the other hand, already extensive. We need not, therefore, be surprised to find that the fore-brain at this stage is dependent to a large extent for its means of respiration, and perhaps also for its nutrition, upon the choroid plexus of the mid-brain, and that a special apparatus is developed for securing a forward flow of the necessary fluid in the brain-cavity. With regard to this fluid itself it is interesting to note in this connection the recently expressed opinion of Minot:† “The pineal region develops a series of structures, which, from their anatomical characteristics, appear to be directly concerned in the formation of the fluid in the cavities of the brain. We may assume that the choroid plexus supplies the main bulk of the fluid, but the gland-like organisation of the epiphysis and of the paraphysis indicates that they supply by secretion special chemical substances to the encephalic fluid.”

* See for example Klein, ‘Quart. Journ. Micros. Sci.,’ vol. 20, N.S., p. 476; Retzius, ‘Biologische Untersuchungen,’ Neue Folge, vol. 6, p. 59; Beard, ‘Anatomischer Anzeiger,’ vol. 3, p. 902.

† ‘American Journal of Anatomy,’ vol. 1, No. 1, p. 96.

Considering how much attention has of late years been devoted to the study of the Lamprey's brain, it seems almost incredible that such definite structures as the ciliated grooves described above should have hitherto escaped observation. I have, however, been unable to find any reference to them in the literature available. It remains to be seen whether or not they occur in the adult. I am inclined to think that they probably disappear when the development of the first choroid plexus renders their presence no longer necessary, and such circulation of the fluid in the cavity of the brain as is requisite may be safely left to the cilia lining other parts. Ahlborn* figures a transverse section of the brain of *Petromyzon planeri* taken in the region of the posterior commissure, but makes no mention of the structures in question. Gaskell† also figures a transverse section through the corresponding region of the brain of what he terms "an *Ammocetes* immediately after its metamorphosis," without giving any indication of the ciliated grooves. It seems highly probable, then, that they are really absent in the adult animal, and that their loss is to be looked upon as another of those striking changes which accompany the transformation of the larval *Ammocetes* into the adult *Petromyzon* in Europe, or the closely allied *Geotria* in New Zealand.

Much more remarkable than the apparent absence of the ciliated grooves in the adult is the fact that they seem, so far as I have been able to discover, to have entirely escaped the notice of those investigators who have so minutely described the development of the Lamprey. Thus in the beautiful memoirs of Shipley‡ and Scott§ I can find no reference at all to any such structures.

The general appearance and structure of the ciliated grooves forcibly call to mind the occurrence of more or less similar organs in other divisions of the animal kingdom. We may, for example, compare them physiologically with the siphonoglyphs of Aleyonarians, the ambulacral grooves of Echinoderms, and the endostyle of Amphioxus and the Tunicates. It is generally admitted that the function of all these organs is to bring about the movements of fluids in definite directions, and by analogy we may, I think, pretty safely conclude that a similar function is performed in the case under discussion. One is also tempted to institute a physiological comparison with the ciliated tubes in connection with the brain of the Nemertines, but in the present state of our knowledge such a comparison can be of but little value.

* Ahlborn, "Untersuchungen über das Gehirn der Petromyzonten," 'Zeit. Wiss. Zool,' vol. 39, p. 191, Plate 14, fig. 26.

† Gaskell, "On the Origin of Vertebrates from a Crustacean-like Ancestor," 'Quart. Journ. Micros. Sci.,' vol. 31, N.S., p. 379, Plate 25, fig. 3.

‡ Shipley, "On some Points in the Development of *Petromyzon fluviatilis*," 'Quart. Journ. Micros. Sci.,' vol. 27, N.S., p. 325.

§ Scott, "Notes on the Development of *Petromyzon*," 'Journal of Morphology,' vol. 1, p. 253.

Probably, however, the closest physiological parallel is really to be found in the ciliated groove which, according to Beard, is to be found lying "at the base" of the neural tube in the embryos of nearly all vertebrates,* and which also doubtless serves to promote the circulation of the fluid in the cavity of the central nervous system.

DESCRIPTION OF FIGURES.

All the figures, except fig. 2, were drawn with the aid of the camera lucida under Zeiss objective A, with eyepiece No. 3. Fig. 2 was drawn with the aid of the camera under Zeiss objective D, eyepiece No. 3.

Fig. 1. Transverse section of the brain of the New Zealand Ammocete through the region of the posterior commissure.

Fig. 2. Portion of similar section of the same specimen a short distance in front of the last, showing the histological structure of the ciliated grooves.

Fig. 3. Transverse section of the same specimen just behind the posterior commissure, showing the ingrowth of the choroid plexus of the mid-brain to form a vertical septum.

Fig. 4. Transverse section of the brain of the Owens College Ammocete through the region of the posterior commissure.

Fig. 5. Similar section through the region of the recessus sub-pinealis.

Fig. 6. Similar section at about the level of the hinder margin of the posterior commissure.

Explanation of Lettering.—*Ar. T.*, arachnoidal tissue. *C.G.*, ciliated groove. *Ch. Pl.*, choroid plexus. *Com. P.*, posterior commissure. *G.H.R.*, right ganglion habenulæ. *Inf.*, Infundibulum. *Iter*, aquæductus Sylvii or iter. *M.b.l.*, left Meynert's bundle. *M.b.r.*, right Meynert's bundle. *M.C.*, connective tissue brain case (membranous cranii). *R.S.*, recessus sub-pinealis or infra-pinealis. *Tr.*, trabeculæ cranii. *V. 3*, third ventricle.

* 'Anatomischer Anzeiger,' vol. 3, pp. 902, 903.

FIG. 1.

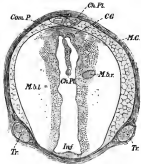


FIG. 2.

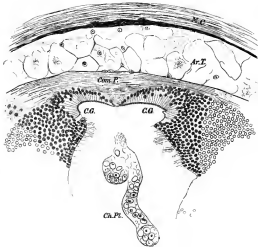


FIG. 3.

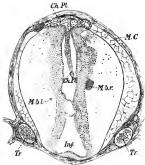


FIG. 4.

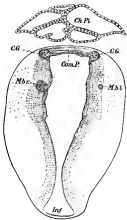


FIG. 5.

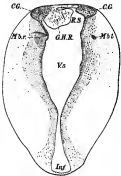


FIG. 6.

